Portable Neutron Detector

User's Manual

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1. Overview

The portable, directional thermal neutron detector simultaneously detects both gamma radiation and thermal neutron particles and displays the detection information on a hand-held personal data assistant (PDA) in terms of count and rate. Both the neutron and gamma count along with gamma spectral data are sent and displayed on the PDA via RS-232 communication from a digital pulse processor (DP4) at a rate of one Hertz. This information is saved onto the PDA for data analysis.

This highly sensitive neutron detector weighs only 10 lbs, can be scanned over an area of interest, and in a few seconds detect the presence and location of neutron-emitting nuclear materials through both a visual and audio alarm. Software on the PDA allows the user to customize parameters of the counting operation and provides enhanced functionality. This includes the ability to either automatically set the alarm thresholds based on a brief background measurement or to manually adjust the alarm thresholds, change the integration (averaging) time, and control the audio alarms. Other functions include the ability to manually save the data, turn high voltage to the detector on or off, pause the current acquisition, or to clear the data and start a new acquisition.

2. Set-Up Instructions

The portable, directional thermal neutron detector is packaged neatly into a protective carry case as shown in Figure 1 containing all necessary components for operation.

Figure 1. Portable Neutron Detector, PDA, Cables, and Equipment in Carrying Case.

2.1. Hardware connections (See Table 1 for cable connector Supplier and PN)

1) Connect the 6 pin circular cable and LEMO cable from the detector to the DP4 as shown in Figure 2. The cables are reversible.

Figure 2. 6 Pin Circular Cable Connected from Detector to DP4.

2) Connect the RS-232 cable from the PDA to the DP4 4 pin circular serial connector (Figure 3).

Description	Supplier	Supplier PN
LEMO RF Connector	LEMO, USA	FFS.00.250.CTCE31
6 Pin Circular Connector	BTC Electronic Components	MS3116F10-6S
4 Pin Circular Connector	BTC Electronic Components	MS3116F8-4S
PDA RS-232 Cable	SunetekStore.com	RS232 Serial Cable for iPAQ 3800

Table 1. Cable Connector Supplier and PN.

Figure 3. 4 Pin Circular Cable Connected from DP4 to PDA.

2.2. Software installation

1) Install Microsoft ActiveSync on the host PC, connect the PDA to the PC with the PDA cradle as illustrated in the PDA's manual.
2) Install a SD card into the PDA's SD slot.
3) Once the PDA is connected to the PC with ActiveSync, click on the Explore button found on the ActiveSync window as shown in Figure 4.

Figure 4. ActiveSync GUI.

4) Change to the following folder: \Windows\Start Menu\Programs.
5) Insert the Installation CDROM, open a new explorer window and select the DTRA Acquisition Software (DTRA.exe) file on the CDROM. Copy the file.
6) Select the PDA's explorer window opened in step 3 and paste the file into the \Windows\Start Menu\Programs folder.
7) Change the directory on the PDA to \Storage Card.
8) Return to the explorer window opened in step 5 and copy the config.dp4 file from the CDROM.
9) Return back to explorer window for the PDA and paste into the \Storage Card directory.

2.3. Power On

Install a battery into the battery pouch and ensure that the battery is connected to the DP4 via the power connection as illustrated in Figure 5.

1) Turn on power to the DP4 with the power switch in the ON position.
2) Power on the PDA and launch the DTRA Acquisition software.
3) The battery is a 3.7 V, 6600 mAh rechargeable Lithium-Ion battery that will provide up to 16 hours of DP4 and detector operation. Table 2 shows PN's and supplier information for the battery connections. This battery does not provide power to the PDA.

Figure 5. Installed Lithium Ion Battery.

4) Turn on power to the DP4 with the power switch in the ON position.
5) Power on the PDA and launch the DTRA Acquisition software.

The power to the DP4 must be turned on with good serial connection prior to launching the DTRA Acquisition software. The screen should look as shown in Figure 6.

Description	Supplier	Supplier PN
Male Battery Connector	Mouser	538-03-06-2023
Pin	Mouser	538-02-06-2103
Female Battery Connector	Mouser	538-03-06-1023
Pin	Mouser	538-02-06-1103
Male Power Plug	Newark	35K3584

Table 2. Battery and Power Connector Supplier and PN.

3. DTRA Acquisition Software

The DTRA acquisition software is written in LabView for PDA 7.1. Default values are shown and described below where appropriate. Because of the limited size of the display on most PDA's, the DTRA Acquisition Software utilizes three tabs called Collection, Configure, and Presets to display different types of data and controls. In addition to the tabs, there are control buttons along the top which are always visible.

3.1. Main Buttons and Indicators for the DTRA Acquisition Software (Figure 6)

- On/Off Indicator: Displays the status of the DP4. ON signifies that the DP4 is collecting data.
- Save Button: Saves the current spectrum to a new file on the SD storage card on the PDA. The file's name will be spectrum_<current date and time>.txt.
- Pause Button: Pauses or resumes the current collection. When the button is lit, it signifies that the DP4 has been commanded to be paused.
- HV Button: Turns the high voltage on the detector on or off. When the button is lit, it signifies that the high voltage is on.
- Reset Button: Clears the following parameters: Rate, Count, Total, Collection Time, and the spectrum.
- Exit Button: Exits the program.

3.2. Collection Tab for the DTRA Acquisition Software (Figure 6)

- Neutron Indicator: Provides a visual indication that the neutron threshold has been exceeded.
- Gamma Indicator: Provides a visual indication that the gamma threshold has been exceeded.
- Rate: Displays the neutron and gamma rates averaged over a sliding window specified by the averaging time in the configure tab with units of counts per second (cps).
- Total: Displays the total neutron and gamma counts since the collection time started (t = 0).
- Count: Displays the increase in total neutron and gamma counts from the previous total.
- Collection Time: Displays the duration of the present collection.

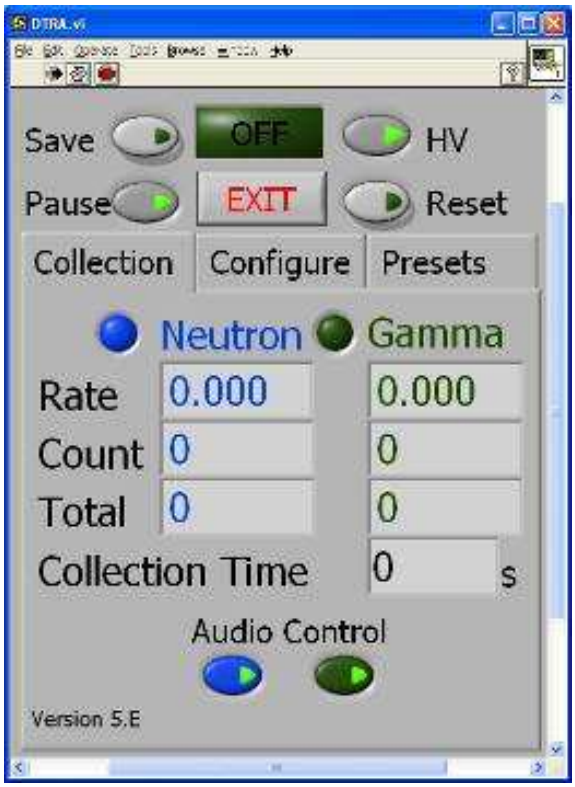

Figure 6. Button, Indicators, and Collection Tab GUI for the DTRA Acquisition Software.

- Audio Control: The left button controls the audio for the neutron alarm and the right for the gamma alarm. An alarm is sounded when the rate exceeds the alarm threshold. When the button is lit, it indicates that the audio is on.

3.3. Configure Tab for the DTRA Acquisition Software (Figure 7)

- Averaging Time: Controls the width of the sliding window over which the neutron and gamma rates are integrated.
- Neutron Alarm: Neutron alarm threshold which can manually be adjusted with units of counts per second (cps).
- Neutron BG: Neutron background rate with units of counts per second (cps). Measured when the Set Alarm button is selected.
- Gamma Alarm: Gamma alarm threshold which can manually be adjusted with units of counts per second (cps).
- Gamma BG: Gamma background rate with units of counts per second (cps). Measured when the Set Alarm button is selected.
- Set Alarms Button: Starts a background measurement for 300 seconds (5 min) to automatically determine the neutron and gamma alarm thresholds according to the following equation: $P = R_b + nx\sigma / T_c$ where R_b = background rate, T_c = averaging time, σ = standard deviation of background ($\sqrt{R_b x T_c}$), n = # of standard deviations (set to 4). When the button is lit, it signifies that the background is currently being measured.

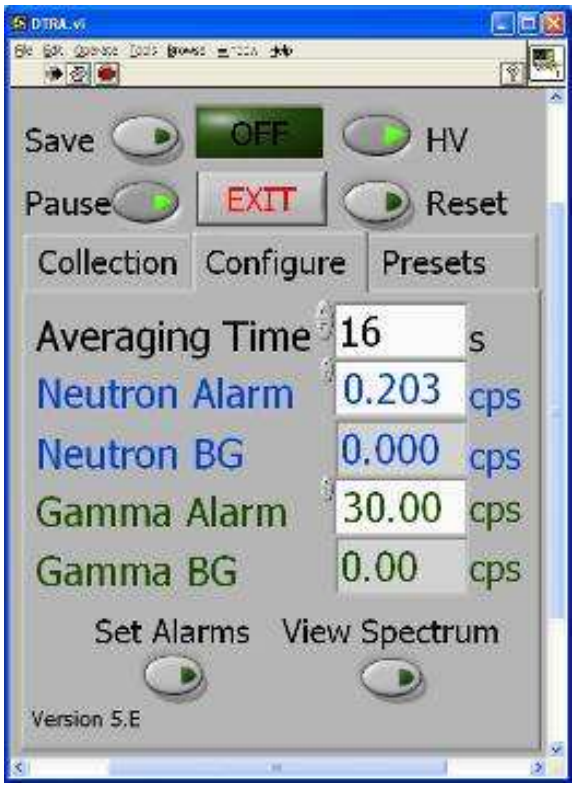

Figure 7. Configure Tab GUI for the DTRA Acquisition Software.

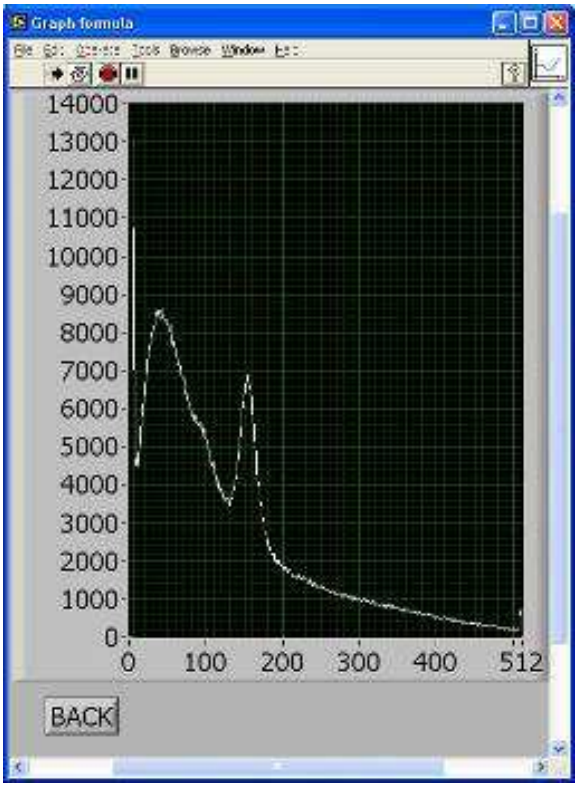

Figure 8. Energy Spectrum GUI for the DTRA Acquisition Software.

- View Spectrum: Displays the current energy spectrum in a new window. The current collection is paused while the spectrum is displayed and resumes when the spectrum display is closed by pressing the BACK button. The x-axis is the channel number and the y-axis is the number of counts. The linear scales automatically adjust to display the data. Currently, the energy spectrum is provided in 512 channels as shown in Figure 8 above.

3.4. Presets Tab for the DTRA Acquisition Software (Figure 9)

When the presets are used by selecting the Use Preset button, they are combined into an "or" operation but with presets of zero ignored. When the preset condition is met, it will pause the current collection.

- Preset Time: Condition is Collection Time = Preset Time.
- Preset Neutron (count): Condition is Total Neutron Count >= Preset Neutron.
- Preset Gamma (count): Condition is Total Gamma Count >= Preset Gamma.
- Use Preset Button: Allows the use of presets. When the button is lit, it signifies that presets are being used.

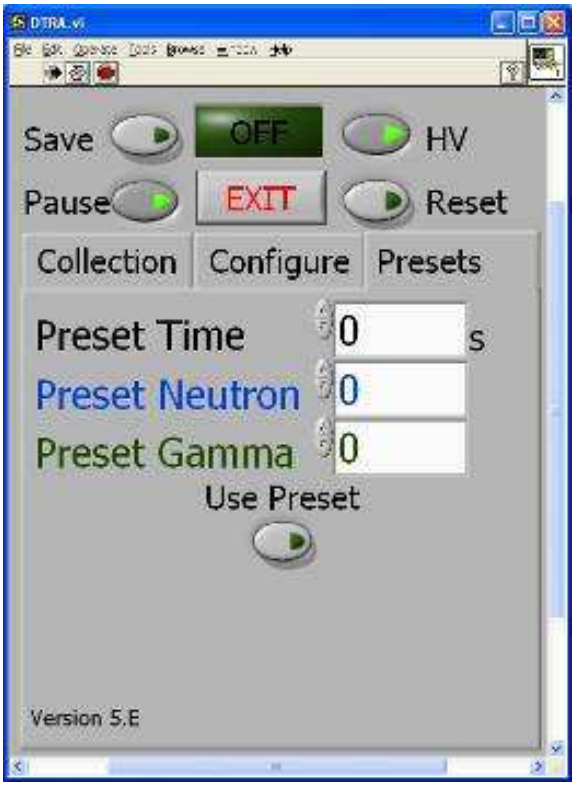

Figure 9. Presets Tab GUI for the DTRA Acquisition Software.

3.5. DTRA Acquisition Software Details

The DTRA Acquisition software reads from a file on the storage card called config.dp4 that is used to configure the DP4. Without this file, the software will exit.

This software will automatically configure the serial port on the PDA for proper operation with the DP4 with the following parameters: 57600 baud, 8 bits, 1 stop bit, and no parity bit.
The DTRA Acquisition software will create two new files on the SD storage card on the PDA: a data file and spectrum file. The names of the files are data_<current date and time>.txt and spectrum_<current date and time>.txt. The data file stores the current neutron count, integrated rate, and threshold, gamma count, integrated rate, and threshold with a time stamp at a rate of once per second (1 Hz) in a tab delimited format as shown in Table 3. Also, a button press is reported with a time stamp in the data file. The spectral data is saved at a rate of 1 Hz, overwriting the existing spectrum. For permanent storage, the save command will save the current spectrum to a new file.

Time Stamp (hh:mm:ss)	Neutron Count	Neutron Integrated Rate (cps)	Neutron Alarm Threshold (cps)	Gamma Count	Gamma Integrated Rate (cps)	Gamma Alarm Threshold (cps)
Time Stamp (hh:mm:ss)	Button Press					

Table 3. Data File Information Header.

A third file called angular.txt will either be overwritten or created if it does not already exist on the SD card of the PDA. This tab delimited file contains only the neutron and gamma counts and is updated at 1 Hz.

Once the DTRA Acquisition software is launched, wait for two full minutes for the high voltage to fully ramp up and stabilize. After the high voltage has stabilized, set the neutron and gamma alarm thresholds by pressing the Set Alarms button.
The Set Alarms button will measure the background neutron and gamma rates over a 5 minute period and will automatically calculate the neutron and gamma alarm thresholds. Save the spectral data before the background measurement is initiated. Setting the alarm thresholds is accomplished by selecting the Configure Tab and then selecting the Set Alarms button. Press the Pause button if a collection is not already running. The Set Alarms button will remain lit during the background measurement. The following parameters will be changed: the Use Preset button will be lit, the Preset Time set to 300 sec (5 min), and the Integration Time set to 16 seconds. The alarm thresholds are calculated according to the following formula: $P = R_b + nx\sigma / T_c$ where R_b = background rate, T_c = averaging time, σ = standard deviation of background ($\sqrt{R_b x T_c}$), n = # of standard deviations (set to 4). When the background measurement is completed, the collection will pause, the light on the Set Alarms button will turn off, the light on the Use Preset button will turn off, Preset Time will zero and Integration Time will remain at 16 seconds. Save the spectral data once the background measurement has been completed.

Once the alarm thresholds have been set, the detector is ready to be utilized for neutron and gamma detection.

The audible alarm frequency is directly proportional to the amount the rate exceeds the alarm threshold. For example, if the rate is two times larger than the threshold, the alarm will sound with twice the frequency but with the same tone.

4. Hardware Test Ports

4.1. Detector Electronics

The portable, highly sensitive neutron detector is comprised of two basic parts: the actual detector and its electronics. The electronics includes the high voltage power supply, a charge sensitive preamplifier, and the neutron shaping and discriminating circuitry. On one of the faces of the detector housing, there are three access ports (Figure 10) from the electronics: a test input port, the preamp out port, and a neutron discriminator output test port. These ports are hermitically sealed LEMO connectors. The detector has no test ports available to it.

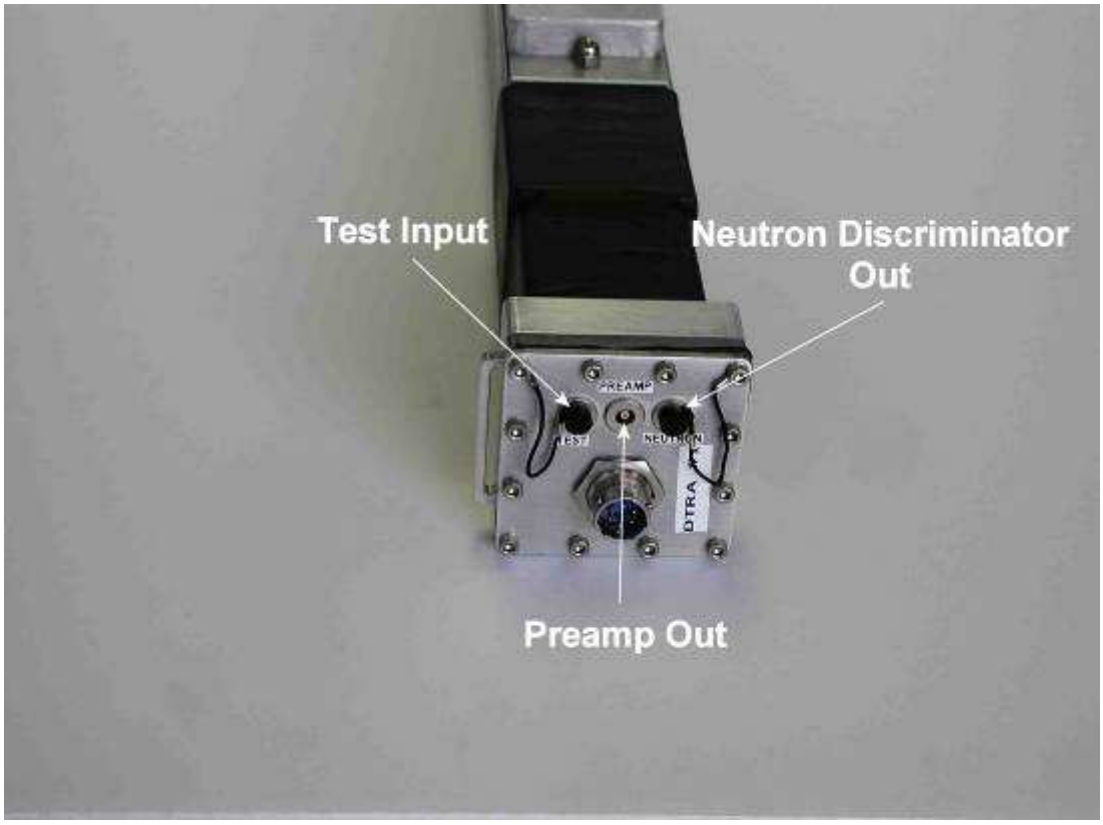

Figure 10. Detector Test Ports.

4.1.1. Test Input Port

The test input port is used to input a signal to the preamp which represents an event that has been detected by the detector. It is a negative going pulse, with a

fast rise time, long tail or slow fall time, at a repetition slow enough so that the tail will fall to the baseline before the next pulse is generated.

4.1.2. Preamp Out Port

The output of this port is a positive going signal from a charge sensitive preamp and is normally connected to the DP4 for gamma discrimination (see Figure 2.)

4.1.3. Neutron Discriminator Out Test Port

This port is a monitor of the output of the neutron discriminator which is a 35 μs long positive going square pulse representative of each detected neutron event which is counted by the DP4.

Figure 11. DP4 Test Ports.

4.2. DP4

As shown in Figure 11, the DP4 has two test ports available: the INH test port and DAC test port. Shown in Figure 2 is the Preamp Input Port which is on the opposite end of the DP4 from what is shown in Figure 11. Configuration software, also provided on the CD-ROM, allows for selection of the DAC outputs found in section 4.2.2.

4.2.1. INH Test Port

This port is a monitor of the signal generated by the detector electronics to inhibit the DP4 from collecting data while the high voltage power supply (HVPS) is increasing the voltage to the detector. The INH signal is used to prevent noise

generated by the HVPS from being counted as events. This is a normally high signal (+3.3V) that will go low (0 V) when the HVPS is on and is applied to the DP4 gate input with a width of 1 ms at a rate of 5 Hz for an approximate .5% duty cycle. When low, events are excluded from the spectrum and count.

4.2.2. DAC Test Port

The DAC test port supplies diagnostic signals from the DAC with an output range of 0 – 1 V. Care should be taken in grounding this connector externally, as ground currents can disturb the analog front end of the DP4. One of two signals are available, the shaped pulse and the decimated input. The shaped pulse is a signal that is a result of the shaping circuitry within the DP4. The decimated input is a representation of the input signal to the analog front end of the DP4. The DAC is normally turned off to conserve power.

4.2.3. Preamp Input Port

This port connects to the Preamp Out Port of the detector (see Figure 2) and is a positive going signal from a charge sensitive preamp from 0 – 100 mV and is used for gamma discrimination by the DP4.

5. Troubleshooting and Errors

- **PDAFileNew() Error code: 6 –** The number of files on the SD exceeds the number of files allowed by the OS. Pocket PC 2003 OS limits the number of files on the SD card to 127. Delete data and spectrum files on the SD card of the PDA.
- **PDAFileNew() Error code: 7 –** The PDA cannot find the config.dp4 file on the SD card. Check to see if the SD card is installed and that it contains the file config.dp4.
- **Read Spectrum Error code: 7 –** The PDA has lost communication with the DP4. Check the RS-232 cable, make sure that the DP4 is powered on before starting the DTRA Acquisition software, or replace the DP4's battery.
- **Read Status Error code: 7 –** The PDA has lost communication with the DP4. Check the RS-232 cable, make sure that the DP4 is powered on before starting the DTRA Acquisition software, or replace the DP4's battery.
- **Serial Port Init Error code: 55 –** A conflict has arisen within the PDA Operating System in initializing its serial port. Reboot the PDA according the PDA's user manual.